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The principal goal of this research was to understand the nature and mechanism of crustal recycling on Venus given that evidence of terrestrial style plate tectonics is lacking. The specific objectives are: (1) to determine the P-T boundaries of the gabbro-granulite-eclogite transition from near solidus conditions to the lowest pressure and temperatures that are kinetically accessible, (2) to model the process and effects of negative diapirism induced by the transformation of gabbro crust to dense eclogite with emphasis on the surface tectonic and volcanic features that might result and analyze the petrological and tectonic consequences of this form of crustal recycling in the context of the model described by Parmentier and Hess (1992). Substantial progress has been made in all of these endeavors.

Task 1: Phase Boundaries for the Granulite-Eclogite Transition

The phase boundaries at Venusian crustal pressure and temperatures were estimated in two ways. We have applied the techniques of mineral equilibrium thermometry and barometry to constrain the pressures and temperatures of natural occurring terrestrial eclogite and granuilite (basaltic) rocks (Herzog et al., 1995, to be submitted). Over 53 data points were collected from the literature to define the eclogite-field from 500°C to 1.3 GPa to 800° and 1.8 GPa. No eclogites were found below 400°C. More than 50 data points were used to define the granulite facies. Maximum P-T conditions for the granulite facies lie from 700°C, 0.5 GPa to 1000°C, 1.2 GPa.

Experiments were performed in a piston-cylinder apparatus olivine-normative ocean floor basalts with Mg* values of 0.71 and 0.63. Because the kinetics of the granulite-eclogite transition are extremely sluggish at temperatures below 1000°C we have experimented with a number of fluxes that are capable of accelerating mineral reaction rates without influencing the phase equilibria. After an extensive experimental investigation we have found the PbO-PbF_2 fluxes serve our purposes well. We have successfully run experiments at 1100°C to 900°C and now are focusing on the critical low temperature regime below 900°C.

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Task 2:

Models for the vertical accretion of a basaltic crust and depleted mantle layer on Venus over geologic time predict the eventual development of a net negatively buoyant depleted mantle layer, its foundering and its remixing with the underlying mantle We have investigated consequences of the development of this layer, its loss, and the aftermath and compared the model to the geologic record of Venus revealed by Magellan. The young average age of the surface of Venus (several hundred million years), the formation of the heavily deformed tessera regions, the subsequent emplacement of widespread volcanic plains, the presently low rate of volcanic activity, an impact crater population that cannot be distinguished from a completely spatially random distribution, and the small number of impact craters embayed by volcanism, are all consistent with the development of a depleted mantle layer, its relatively rapid loss followed by large-scale volcanic flooding, and its subsequent re-establishment. A 'catastrophic' tectonic resurfacing model in which the foundering of the depleted mantle layer several hundred million years ago caused globally extensive tectonic deformation and obliteration of the cratering record, accompanied by upwelling of warm fertile mantle and its pressure-release melting to produce extensive surface volcanism in the following period. Venus presently appears to be characterized by a relatively thick depleted mantle layer and lithosphere reestablished over the last several hundred million years following the previous instability event inferred to have produced the tessera terrain.

On a planet with plate tectonics, like the present day Earth, the oceanic lithosphere including the basaltic crust is recycled into the mantle at convergent plate boundaries. On a volcanically active planet with no plate tectonics such as Venus, it is important to understand how crust that thickens with time can be recycled. Rayleigh-Taylor (R-T) instability due to the basalt-eclogite transition at the base of a thickening or cooling crust is an obvious mechanism. But what is the rate and scale of this process and what would its surface manifestation be? Does crustal instability occur as a fine eclogite rain or as a mantle downwelling at the scale of compressional highlands? Equating the growth rate of R-T instability $\Delta\rho g h/4\mu_1$ with the rate of layer thickening $\Delta h/h$ gives an estimate of the layer thickness $h=(4\mu_1/\Delta\rho g)^{1/2}$ at which the formation and sinking of eclogite diapirs balances the rate of eclogite creation. Here $\Delta\rho$ is basalt-eclogite density difference, μ_1 is the eclogite viscosity, and g is the gravitational acceleration. The wavelength of instability, assuming that the viscosity of underlying mantle, μ_m, is less than the eclogite layer, is $\lambda=4\pi h(\mu_1/\mu_m)^{1/5}$. Since the basalt-eclogite transition is exothermic, the creation rate of eclogite could be controlled by heat loss by conduction to the surface so that $h=k\Delta T/Hd$ where k is the thermal conductivity, ΔT is the temperature difference between the base of the crust and the surface, H is the hat reaction, and d is the crustal thickness. For crustal thickness of a few tens of kilometers and reasonable values of other parameters, this gives a horizontal scale of about 20 km and an eclogite diapir diameter $(4\lambda^2 h/\pi)^{1/3}$ of about 10 km. However, this order of magnitude estimate depends strongly on the thermodynamic properties and kinetics of the basalt-eclogite phase transformation at the temperature present near the bottom the Vensian crust.

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